STUDY OF ELASTIC-PLASTIC AND CREEP DEFORMATION PROBLEMS IN MECHANICS

SYNOPSIS

Submitted in partial fulfilment of the requirements for the award of the degree of
Doctor of Philosophy

Submitted by

Meenu Koul
Enrollment No.: H13241

Under the supervision of

Co-Supervisor
Dr. Pankaj
Associate Professor,
ICFAI University, Solan
(H.P.)

Supervisor
Dr. Rajender Kumar
Associate Professor
Department of Physics
School of Basic & Applied Sciences,
Career Point University, Hamirpur
(H.P.)

DEPARTMENT OF PHYSICS
SCHOOL OF BASIC & APPLIED SCIENCES
CAREER POINT UNIVERSITY HAMIRPUR
TIKKER (KHARWARIAN), BHORANJ
HAMIRPUR (HP)-176041, INDIA

Academic Session: 2020-21

CONTENTS

1. Introduction.
2. Literature review.
3. Significance of the study.
4. Proposed methodology.
5. Objectives of the study.
6. Thesis outline.
7. Research plan schedule.
8. References.

1. INTRODUCTION

Mechanics of Solids deals with the mechanical behavior of the deformable bodies (bars, plates, cylinder, disc, shell etc.) subjected to various types of external forces and goes by a variety of names, such as strength of materials, mechanics of deformable solids etc. Research in solid mechanics is not only for the basic understanding of mechanical phenomenon but also for the advanced engineering techniques in most of the areas throughout mechanical and structural technology. Advances in the subject are central to assure safety, reliability and economy in the design of device, structure and complete systems, and hence to the continued development of power generation technology such as nuclear fusion and gas turbines, aerospace and surface transportation vehicles, earthquake resistant design, offshore structures, orthopedic devices, material processing and manufacturing technologies.

Concepts of stress, strain and elasticity. The English scientist Robert Hooke discovered in 1660, but published only in 1678, the observation that for many materials that displacement under a load was proportional to force, thus establishing the notion of (linear) elasticity but not yet in a way that was expressible in terms of stress and strain. E. Mariotte in France published similar discoveries in 1680 and, also, reached an understanding of how beams like those studied by Galileo resisted transverse loadings or, more precisely, resist the torques caused by those transverse loadings, by developing extensional and compressional deformations, respectively, in material fibers along their upper and lower portions. It was for Swiss mathematician and mechanician James Bernoulli (1654-1705) to observe, in the final paper of his life, in 1705, that the proper way of describing deformation was to give force per unit area, or stress, as a function of the elongation per unit length, or strain, of a material fiber under tension. Swiss mathematician and mechanician Leonhard Euler (1707-1783), who was taught mathematics by James' brother John Bernoulli (1667-1748), proposed, among many contributions, a linear relation between stress and strain in 1727, of form = E where the coefficient E is now generally called Young's modulus after English naturalist Thomas Young who developed a related idea in 1807. The notion that there is an internal tension acting across surfaces in a deformed solid was expressed by German mathematician and physicist Gottfried Wilhelm Leibniz in 1684 and James Bernoulli in 1691. Also, Bernoulli and Euler (see below) introduced the idea that at a given section along the length of a beam there were

internal tensions amounting to a net force and a net torque. Euler introduced the idea of compressive normal stress as the pressure in a fluid in 1752. The French engineer and physicist Charles-Augustine Coulomb (1736-1806) was apparently the first to relate the theory of a beam as a bent elastic line to stress and strain in an actual beam, in a way never quite achieved by Bernoulli and, although possibly recognized, never published by Euler. He developed the famous expression = M y / I for the stress due to the pure bending of a homogeneous linear elastic beam; here M is the torque, or bending moment, y is the distance of a point from an axis that passes through the section centroid, parallel to the torque axis, and I is the integral of y2 over the section area. The French mathematician Parent introduced the concept of shear stress in 1713, but Coulomb was the one who extensively developed the idea in connection with beams and with the stressing and failure of soil in 1773, and studies of frictional slip in 1779. It was the great French mathematician Augustin Louis Cauchy (1789-1857), originally educated as an engineer, who in 1822 formalized the stress concept in the context of a general three-dimensional theory, showed its properties as consisting of a 3 by 3 symmetric array of numbers that transform as a tensor, derived the equations of motion for a continuum in terms of the components of stress, and gave the specific development of the theory of linear elastic response for isotropic solids. As part of this work, Cauchy also introduced the equations which express the six components of strain, three extensional and three shear, in terms of derivatives of displacements for the case when all those derivatives are much smaller than unity; similar expressions had been given earlier by Euler in expressing rates of straining in terms of the derivatives of the velocity field in a fluid.

Elasticity deals with the systematic study of stress, strain and displacement in an elastic body under the influence of external forces. All structural materials posses to a certain extent the property of elasticity, that is, if external forces producing deformation of a structure do not exceed to a certain limit, the deformation disappears with the removal of the forces. For various engineering disciplines the purpose of studying elasticity is to analyze the stresses and displacements of structural and machine elements in the range and thereby to check the sufficiency of their strength, stiffness and stability.

The theory of plasticity is the name given to the mathematical study of stress and strain in plastically deformed solids. This follows the well-established precedent set up by the ‘theory of elasticity’. The relation of plastic and elastic properties of

metals to crystal structures and cohesive forces belongs to the subject now known as ‘metal physics’. The theory of plasticity takes, as its starting point, certain experimental observations of the macroscopic behaviors of a plastic solid in uniform states of combined stress. The task of the theory is two fold: First, to construct explicit relations between stress and strain agreeing with the observations as closely and as universally as needed and second, to develop mathematical techniques for calculating non-uniform distributions of stress and strain in bodies permanently distorted in any way. Unlike elastic solids in which the state of strain depends only on the final state of stress, the deformation that occurs in plastic solid is determined by the complete history of loading. The plasticity problem is, therefore, essentially incremental in nature, the final distortion of the solid being obtained as the sum total of the incremental distortions following the strain path. The situation in which material deforms continuously to load for a prolonged period of time, usually at elevated temperature, is called ‘creep’ and so a constant load test is called a ‘creep test’. The conventional stress (load divided by initial cross-section) is called the ‘creep-stress’. The gradual strain is called ‘creep-strain’, the strain-time curve one obtains is called the ‘creep-curve’ and the slope of this curve is called the ‘creep-rate’. Creep strains may be elastic, plastic or a combination of these. Creep strain might occur too slowly to detect or too rapidly to follow. Even in such cases, however, there is evidence that creep strain is always time-dependent. For many material including most metals and alloys, elevated temperatures may be applied in order for creep to be produced. Changes in temperature induce thermal expansion and have ill-defined effect upon the material behavior. However, in various non-metallic materials such as plastics, wood and concrete, creep occurs at normal temperatures.

Transition: Transition is a natural phenomenon and there is hardly any branch of science or technology in which we do not come across transition from one state in to another as shown in Figure 1. Elasticity - plasticity, visco-elastic, deformations, creep, fatigue relaxation and adiabatic theory in quantum mechanics is well known examples. At present they are generally treating as discontinuous. For elastic-plastic deformations, the ideal model has to assume some type of yield condition. For creep, not only the yield condition but also a number of creep strain laws have to be assumed. All these assumptions leave the mind a little dissatisfied. More scientific advancements should attempt to reduce these assumptions. This has motivated us to

pay some attention to the treatment of transition problems in the domain of solid mechanics.

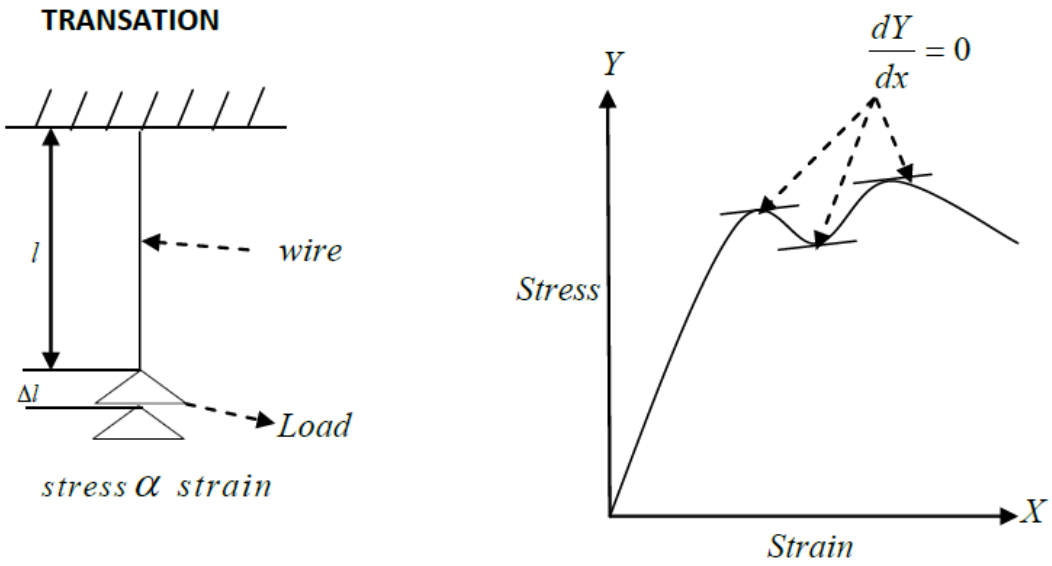

Figure 1. Occurs of Transition point

Theory of elasticity and plasticity describe the mechanics of deformation of most engineering solids. Both the theories as applied to metals and alloys are based on experimental studies of the relation between stress and strain in a polycrystalline aggregate under simple loading conditions. Thus they are of phenomenological nature on the macroscopic scale and, as yet, owe little to knowledge of structure of metals. However, in order to understand the limitations so imposed on the theories, the engineer, with his main interest in design and manufacture must have some knowledge of the structure of metals. The validity of the predictions of any mathematical model of deformation and stress-distribution no matter how carefully constructed depends ultimately on one's ability to assess the mechanical properties and characteristic of the material to be used and to apply these data in the actual calculations. For this reason, testing material properties is a matter of utmost importance for an engineer. No design can possibly be regarded as successful unless it is firmly based on good understanding of the potential of the material and its consequent ability to respond satisfactorily to the proposed system of loading. It is important to realize that any mechanical testing technique no matter how appropriate can provide information only about the average material properties to be generally

expected but can not provide an explanation of why a material behaves in a certain manner. It does not even necessarily follow that data obtained in a test on a specific material will be totally reliable when the material ostensibly the same, but from a different batch, is used in the manufacturing process. We can only expect that in the absence of any unknown internal defects and metallic and non-metallic inclusions. Our alloy will behave in the way suggested by the test results. The basic method for bringing out the behaviour of structural materials is the tensile test.

Elastic-plastic transition is obtained in current literature with the help of semi-empirical yield condition like that of Tresca or von-Mises. The stresses are obtained from the elastic solution and then substituted in the yield condition to get the transition surface. The possibility of treating it as a transition or turning point phenomenon in finite deformation has not been explored. When plastic state tends to set in, the stress-strain relation undergoes a change. This must be reflected in our equations. The linear classical theory cannot do it. Tresca (1868) pointed out that a transition state, which he called mid-zone exists when a material passes from elastic - zone to plastic - zone and this is, later on supported by Todhunter and Pearson (1893). In the transition state whole of the material participates, and not simply a selected region or a line as assumed by classical theories. This is expressed by Sir Lawrence and supported by Bragg (1948). When he points out that an element of a crystal embedded in the matrix shall be pictured as being strained together with the whole mass of the metal and hence slip must take place by a whole intra-atomic distance.

2. LITERATURE REVIEW

Rotating disc play an important role in machine design. The design of elastic-plastic rotating discs has been a subject of longstanding interest with useful and practical applications in industry and engineering such as turbine rotors, compressors, flywheels, high speed gear engines and computer devices etc. The problem of rotating discs was first treated in the early nineteenth century. Solution of the isotropic discs including variable thickness, variable density and other case can be found in most of the standard elasticity textbooks (Arrowsmith, 1923; Heyman, 1958). Rotating discs were considered to be one of the exhausted subjects in the field of solid mechanics. Recently new interest has been generated to reinvestigate this centuries old problem. The new interest is the result of the development of composite materials and their

applications. Composite materials are characterized by high strength to weight ratios, heterogeneity and anisotropy characteristics. Thus rotating disc technique has been proved to be a simple and reliable means of generating a biaxial state of stress when the loads cannot be directly applied to the material under investigation. In this case, an analytical solution of this problem is needed to interpret the experimental results generated in the laboratory. Because of the steady increase in the use of energy and the impact of that use on the environment, a flywheel made of composite materials has been proved to be an efficient mean of storing energy. Likewise, analytical solution of rotating discs made of composite materials is essential in design and analysis. The calculation of turbine disc involves the solution of second order differential equation having the elastic stress function. This equation is integrable analytically for discs of constant thickness, and for specific examples of discs of non-constant thickness. For example, Arrowsmith (1923) has given solutions for discs whose thickness is inversely proportional to radius to the power thickness parameter, while Malkin (1934) discusses exponential disc. For a disc of non-uniform profile, however, the fact that the hoop stress at the hub does not exceed the permissible value tells the designer little more than that the disc is safe at the design speed. One cannot, from this knowledge, alone calculate the percentage over-speed at which the disc will burst or more realistically, at which the diameter of the disc will increase sufficiently to strip the blades. The safety factor on stress is thus replaced by a safety factor on the speed. Attention has been paid recently to the calculation of bursting speed, usually of flat discs made from strain-hardening material. This is of great interest from the stand point of plastic analysis, but the designer is usually more concerned with the speed at which large deformations brings, that is, in flow speed. Unrestricted plastic flow is an unstable plastic flow for a disc unless the material strain-hardens as soon as the whole disc becomes plastic, the radial displacement increases rapidly and the disc bursts. The calculation of the condition at which large displacements begin is likely to be of most interest to the designer.

Many author worked on the problems of disc under various condition as below:

Suresh Hulsurkar (1979) has analyzed thermo elastic plastic transition in rotating disks with steady state temperature. It has been observed that if the additional condition of incompressibility is imposed, then the expression for stresses correspond to those arising from Tresca yield criterion.

S.K. Gupta and R. K. Shukla (1994) have analyzed the effect of non-homogeneity on elastic-plastic transition in a thin rotating disc. It has been observed that in the presence of non-homogeneity ($k > 0$) in thin rotating discs required higher angular velocity for initial yielding as compare to homogeneous disc but less percent increase in angular velocity to become fully plastic against initial yielding and this percentage goes on decreasing with the increase in non-homogeneity. Reverse is the case for $k < 0$.

R. K Shukla (1996) has investigated creep stresses in a thin rotating annular disc made of non-homogeneous material by using transition theory. It has been observed that in the presence of non-homogeneity having lesser value at the bore, reduces the stresses and the angular velocity required for steady state of creep as compared to the homogeneous disc, however, that having higher value at the bore than at the rim, increasing the magnitude of angular velocity and creep stress significantly, and hence increases the possibility of a fracture in the vicinity of the bore.

U. Güven (1997) have analyzed fully Plastic rotating disk with rigid inclusion. The plane state of stress in a fully plastic rotating annular disk mounted on a rigid circular shaft is studied. The analysis is based on Tresca's yield condition, its associated flow rule, and linear strain hardening material behaviour.

U. Güven (1998) has obtained elastic-plastic stress distribution of a rotating hyperbolic annular disk mounted on a circular rigid shaft. The exact solution presented is based on the usual assumptions of plane stress, Tresca's yield condition, its associated flow rule and linear strain hardening material behaviour. According to the present analysis the plastic core consists of three parts with different forms of the yield condition. The theory presented is illustrated by numerical results. The results show that the plastic flow and maximum stresses are influenced by the thickness parameter.

U. Güven (1999) has analyzed plane state of stress in an elastic-plastic rotating annular disk mounted on a rigid circular shaft. The analysis is based on Tresca's yield condition, specifically its associated flow rule and linear strain hardening material behavior. In the present analysis, it is shown that the plastic core adopts three parts, within different forms of the yield condition.

S.K. Gupta et al. (2000) have analyzed creep stresses and strain rates in a thin rotating disc having variable thickness and variable density by using Seth's transition theory. It has been concluded that a rotating disc whose density and thickness ratio

decrease radially is on the safer side of the design in comparison to a flat disc having variable density.

R.K. Shukla (2000) has obtained elastics-plastic transitional stresses in a non-homogeneous disc with variable thickness subjected to internal pressure by using Seth's transition theory. Non-homogeneity in the disc is due to variation of Poisson's ratio of the material. It is found that the presence of non-homogeneity and thickness variation influence significantly the stresses and pressure required for initial yielding. The thickness variation reduces the magnitude of the stresses and pressure needed for fully-plastic state.

Ahmet et al. (2004) have analyzed parametric analysis of rotating variable thickness elastoplastic annular disks with inner boundaries subject to pressure or mounted on rigid inclusion. A computer model based on von Mises yield criterion, J2-deformation theory and nonlinear isotropic hardening is developed. Elastic limit angular velocities, partially plastic deformations and plastic limit angular velocities are investigated with emphasis on the determination of the effects of all the geometric, material and hardening parameters involved.

S. K. Gupta and Pankaj Thakur (2007) have analyzed rotating disc with inclusion and made of compressible material requires lesser angular speed to yield at the internal surface and higher percentage increase in angular speed to become fully plastic as compare to disc made of in compressible material. With effect of thermal rotating disc required lesser angular speed to yield at the internal surface. Rotating disc made of compressible material with inclusion requires higher percentage increase in angular speed to become fully-plastic as compare to disc made of in compressible material. Thermal effect also increases the values of radial and circumferential stresses at the internal surface for fully-plastic state.

S. K. Gupta and Pankaj Thakur (2007) have obtained creep stresses and strain rates for a thin rotating disc with inclusion by using Seth's transition theory. It has been observed that radial stress has maximum value at the internal surface of the rotating disc made of incompressible material as compared to circumferential stress and this value of radial stress further increases with the increase in angular speed. Strain rates have maximum values at the internal surface for compressible material. Rotating disc is likely to fracture by cleavage close to the inclusion at the bore

Pankaj Thakur (2009) has obtained elastic - Plastic transition Stresses in a transversely isotropic thick -walled cylinder subjected to internal pressure and

steady - state temperature by using transition theory. It has been seen that with the increase of temperature, the cylinder having smaller radii ratios requires lesser angular velocity to become fully plastic as compared to cylinder having higher radii ratios

Pankaj Thakur (2009) has analyzed a disc of variable thickness made of compressible material yields at some radius R_1 at a higher pressure as compared to disc made of incompressible material that yields at the outer surface. Flat disc made of incompressible material yields on internal surface at higher pressure as compared to disc made of compressible material. Circumferential stress has maximum at the outer surface of the disc having variable thickness.

Pankaj Thakur (2009) has performed elastic-plastic transition in a thin rotating disc having variable density with inclusion using Seth's transition theory. It has been observed that the rotating disc with inclusion and made of compressible material yields at the internal surface at a lesser angular speed as compared to a disc made of incompressible material whereas it requires a highly percentage increase in angular speed to become fully plastic. Radial stresses are higher at the bore for rotating disc made of incompressible material. It means that rotating disc having variable density and made of compressible material have a tendency to fracture at the bore. Effect of variable density also increases the values of radial and circumferential stresses at the internal surface for fully-plastic state.

Pankaj Thakur (2010) has obtained stresses for the elastic-plastic transition and fully plastic state for a thin rotating disc with rigid shaft at different temperatures. It has been observed that at room temperature rotating disc made of compressible material and of smaller radii ratio yields at the internal surface at a higher angular speed as compared to rotating disc made of incompressible material. With the introduction of thermal effect rotating disc yields at the outer surface at a lesser angular speed as compared to rotating disc at room temperature. The circumferential stress is maximum at the outer surface of the rotating disc with further increases with the increase in temperature. It means that angular speed of the rotating disc is less than that of the temperature-loaded disc in the fully plastic case.

Pankaj Thakur (2010) has calculated creep stresses and strain rates for a thin rotating disc with shaft at different temperature. It has been observed that radial stress has maximum value at the internal surface of the rotating disc made of incompressible material as compared to circumferential stress and this value of radial stress further

increase with the increase of angular speed. With the introduction of thermal effect, it has been observed that radial stress has higher maximum value at the internal surface of the rotating disc made of incompressible material as compared to circumferential stress, and this value of radial stress further increases with the increase of angular speed as compared to the case without thermal effect. Strain rates have maximum values at the internal surface for compressible material. Rotating disc is likely to fracture by cleavage close to the inclusion at the bore.

Pankaj Thakur (2011) has analyzed the problem of creep transition stresses of a Thick isotropic spherical shell by finitesimal deformation under steady state of temperature and internal pressure. It is seen that shell made of incompressible material require higher pressure to yield as compared to shell made of compressible material.

Pankaj Thakur (2011) discussed the problems in an elastic-plastic transition stresses in rotating cylinder by finite deformation under steady-state temperature. It has been seen that with the increase of temperature, the cylinder having smaller radii ratios requires lesser angular velocity to become fully plastic as compared to cylinder having higher radii ratios.

Pankaj Thakur (2011) have analyzed elastic-plastic transitional stresses in an annular disc having variable thickness and variable Poisson's ratio subjected to internal pressure using Seth's transition theory. It is seen that thickness and passion's ratio variation influence significantly the stresses and pressure required for initial yielding. The thickness variation reduces the magnitude of the stresses and pressure needed for fully plastic state. It is seemed for fully plastic state that circumferential stresses is maximum at the outer surface.

Pankaj Thakur (2012) have obtained stresses for the elastic-plastic transition and fully plastic state for a thin rotating disc with rigid shaft having variable thickness by using Seth's Transition theory . It has been observed that in the absence of thickness, rotating disc with inclusion and made of compressible material e.g. Copper, Brass and Steel, yields at the internal surface at a lesser angular speed as compared to a rotating disc made of incompressible material e.g. rubber whereas it requires a higher percentage increase in angular speed to become fully plastic. With the effect of variation thickness, higher angular speed is required to yield at the internal surface. It has been observed that the radial stress maximum at the internal surface. With the effect of variable thickness it increases the value of radial and circumferential stress at

the internal surface for transitional state, whereas it can be seen that rotating disc having variable thickness increases the values of radial and circumferential stress at the internal surface for fully-plastic state.

Pankaj Thakur (2012) has derived the elastic-plastic and transitional stresses using transition theory. It is observed that the rotating disc made of incompressible material with inclusion requires higher angular speed to yield at the internal surface as compared to the disc made of compressible material. It is seen that the radial and circumferential stresses are maximum at the internal surface with and without edge load (for flat disc). With the increase in thickness parameter (k = 2, 4), the circumferential stress is maximum at the external surface while the radial stress is maximum at the internal surface. From the figures drawn the disc with exponentially varying thickness (k = 2), a high angular speed is required for initial yielding at the internal surface as compared to flat disc and exponentially varying thickness for k = 4 onwards. It is concluded that the disk made of isotropic compressible material is on the safer side of the design as compared to disk of isotropic incompressible material as it requires higher increase in an angular speed to become fully plastic from its initial yielding.

Pankaj Thakur et al. (2013) have obtained stresses for the elastic-plastic transition and fully plastic state has been derived for a thin rotating disc having variable thickness with shaft at different temperatures. It has been observed that in the absence of thickness, the rotating disc made of incompressible material e.g. rubber with inclusion require a higher angular speed to yield at the internal surface as compared to a disc of compressible material e.g. copper, brass and steel and a much higher angular speed is required to yield with the increase in radii ratio. With the effect of variation thickness, reverse results and lesser angular speed are required to yield at the internal surface. With the introduction of thermal effects for k = 0, lesser angular speed is required to yield at the internal surface. When thickness varies (say k = 2.5, 5), reverse in the results. The radial stresses is maximum at the internal surface with no thickness, when thickness varies the circumferential stress is maximum at the internal surface.

Pankaj Thakur et al. (2016) discussed the problem in thermal creep transition stresses and strain rates in a circular disc with shaft having variable density. Thermal effect increased value of radial stress at the internal surface of the rotating disc made of incompressible material as compared to tangential stress and this value

of radial stress further much increases with the increase in angular speed as compared to without thermal effect. Strain rates have maximum values at the internal surface for compressible material.

Pankaj Thakur et al. (2017) have analyzed thermal creep stress and strain analysis in Non-homogeneous Spherical shell by using Seth transition theory. With the effect of thermal effect, values of circumferential stress decrease at the external surface as well as internal surface of the spherical shell. It means that the temperature dependent materials minimize the possibility of fracture at the internal surface of the spherical shell.

Pankaj Thakur et al.(2017) discussed the problem in elastic-plastic stress analysis in a spherical shell under internal pressure and steady state temperature by using Seth's transition theory. It has been seen that circumferential stress has a maximum at the external surface of the spherical shell made of incompressible as well as compressible materials. The thermal effect increases the values of stresses.

Pankaj Thakur et al. (2017) has analyzed the problem in elastic-plastic transition on rotating spherical shells in dependence of compressibility. It has been observed that Rotating shells made of the incompressible material are on the safer side of the design as compared to rotating shells made of compressible material. The effect of density variation has been discussed numerically on the stresses. With the effect of density variation parameter, rotating spherical shells start yielding at the internal surface with the lower values of the angular speed for incompressible/compressible materials.

Pankaj Thakur et al.(2017) has analyzed the problem creep strain rates analysis in cylinder under temperature gradient materials by using Seth's theory. Thermal effect increases the values of axial stress at the external surface of a circular cylinder for incompressible material as compared to compressible materials. With the introduction of thermal effects, the maximum value of strain rates occurs at the external surface for incompressible material as compared to the compressible materials.

Pankaj Thakur and Monika Sethi(2020) analyzed the problem Creep deformation and stress analysis in a transversely material disc subjected to rigid shaft by using Transition theory.

Pankaj Thakur, Monika Sethi(2020) investigated the problem Elastoplastic deformation in an orthotropic spherical shell subjected to temperature gradient.

Monika Sethi and Pankaj Thakur (2020) have investigated problem of elastoplastic deformation in an isotropic material disk with shaft subjected to variable density and load using Seth's transition theory. has been observed that the values of angular speed decreased with increases in the values of the density parameter for an incompressible material. Radial stress has the maximum value at the internal surface of the rotating disk made of incompressible material (i.e., rubber) as compared to the compressible materials (i.e., saturated clay and copper).

3. SIGNIFICANCE OF THE STUDY

This research proposal is of importance in the design of Engineering structures e.g. flywheel, turbojet engines, centrifugal compressors, steam and gas turbines, turbo generators, reciprocating engines, brake discs, the casting of ship propellers, etc.

4. PROPOSED METHODOLOGY

Seth B. R. in years 1962 has given transition theory in Elastic-plastic Deformation, Creep and Relaxation in Nature Journal. This theory does not required any assumptions like an yield condition, incompressibility condition and thus posses and solves a more general problem from which cases pertaining to the above assumptions can be worked out. This theory utilizes the concept of generalized strain measure and asymptotic solution at critical points or turning points of the differential equations defining the deformed field.

1) Seth given governing equation by taking following steps:

- Stress- Strain relations
- Equations of Equilibrium
- Compatibility Equations
- Boundary Conditions
- Non-Linear differential Equation.
- Turning points of nonlinear differential equation.

2) Neglect assumptions:

- Incompressibility condition
- A power relationship between Stress and Strain.
- Yield condition such as Tresca or Von-Mises.
- Deformations are assumed to be small to make infinitesimal strain theory applicable.

5. OBJECTIVES OF STUDY

The main objective of this research topic is to develop a consistent analytical model capable to resolve a class of control problems for rotating disc for different materials e.g. isotropic, transversely isotropic and othotropic). Due to the importance of the control problems in practical engineering systems and structures. On the other hand, the importance of the material properties in the burst speed of disks was investigated. The novelty of the current research is to be including control factors such as rotating speed, density parameter, thickness, temperature and mechanical load in the consideration of the optimal performance of the disc.

6. THESIS OUTLINE

In the proposed thesis an attempt will be made to study characterization of materials in the disc under various conditions by using transition theory and generalized strain measure. The tentative chapter wise plan of the thesis has been proposed as under:

Chapter 1: Introduction.

Chapter 2: literature review.

Chapter 3: study elastic-plastic deformation in the in disc made of isotropic/ transversely under various conditions.

Chapter 4: study creep deformation in the in disc for different materials made of isotropic/ transversely isotropic under various conditions.

Chapter 5: study elastic-plastic deformation in the in disc made of orthotropic material under various conditions.

Chapter 6: study creep deformation in the in disc made of orthotropic material under various conditions.

Chapter 7: Conclusions and scope for further research.

7.RESEARCH PLAN SCHEDULE

Research activity	**Progress in months**						
No. of Months	**0**	**6**	**12**	**18**	**24**	**30**	**36**
Course works, extended literature review							
Construction of theoretical framework/model							
Determination of stress and strain/ rates							
Result and discussion							
Publication							
Thesis writing							

8. REFERENCES

1. B.R. Seth, Transition Conditions, the Yield Condition, Int. J. Non-linear Mechanics, Vol. 5, pp. 279-285, 1970.
2. B.R. Seth, Transition Theory of Elastic-Plastic Deformation, Creep and Relaxation, Nature, Vol. 195, No. 4844, pp. 896-897, 1962.
3. Bragg, Lawrence, Nature, 149, 511; Phys. Soc., 26, 1948.
4. Civalek, Ö. and Gürses, M., Free vibration analysis of rotating cylindrical shells using discrete singular convolution technique. International Journal of Pressure Vessels and Piping, Vol. 86, no. 10, pp. 677-683, 2009.
5. Eberlein, R. and Wriggers, P., FE concepts for finite elastoplastic strains and isotropic stress response in shells: theoretical and computational analysis. Comput. Meth. Appl. Mech. Eng., Vol. 171, pp.243–279, 1999.

6. G. Arrowsmith, The design of rotating discs, Engineering, London, 116, pp. 417, 1923.
7. H. Tresca, 'M'emoire Sur I Ecoloment Descrops Solids', M'eoire presente's Par Divers Savents., 18, pp. 733 -799, 1868.
8. I. Malkin, Design and calculation of steam turbine disk wheels, T*rans. AMER. Soc. Mech. Engrs.*, 56, pp. 585, 1934.
9. I. Todhuter and K. Peason, History of Elasticity and Strength of Material, 2, pp. 104, 1893.
10. J. Chakrabarty, (1987): Theory of Plasticity. McGraw-Hill Book Coy., New York.
11. J. Heyman, Plastic design of rotating discs, Proc, Inst. Mech. Engrs, 172, pp. 531-546, 1958.
12. King, R.H., Mackie, W.W., Creep of thick-walled cylinders, Jr. Basic Engrs., 87, pp. 877-879, 1969.
13. Monika Sethi and Pankaj Thakur, Elasto-plastic deformation in isotropic material disk with shaft subjected to load and variable density, Journal of Rubber Research, 23(2), pp. 69-78, 2020.
14. N. Ahmet and Eraslan Yusuf Orcan, A parametric analysis of rotating variable thickness elastoplastic annular disks subjected to pressurized and radially constrained boundary conditions, *Turkish J. Eng. Env. Sci.*, Vol. 28, pp. 381 – 395, 2004.
15. Pankaj Thakur, Elastic-plastic transition in a thin rotating disc having variable density with inclusion, *Structural Integrity and Life*, Vol.9, No 3, pp. 171-179, 2009.
16. Pankaj Thakur, Elastic - Plastic Transition Stresses in a transversely isotropic Thick -walled Cylinder subjected to internal Pressure and steady - state Temperature, Thermal Science, Volume 13, Number 4, pp. 107-118, 2009.
17. Pankaj Thakur, Elastic-plastic transition stresses in an isotropic disc having variable thickness subjected to internal pressure, *Structural integrity and life*, Vol.9, No2, pp. 125-132, 2009.
18. Pankaj Thakur, Elastic-plastic transition stresses in a thin rotating disc with rigid inclusion by infinitesimal deformation under steady-state temperature, *Thermal Science,* Vol. 14, Issue 1, pp. 209-219, 2010.

19. Pankaj Thakur, Creep transition stresses in a thin rotating disc with shaft by finite deformation under steady-state temperature, *Thermal Science*, Vol. 14, Issue 2, pp. 425-436, 2010.
20. Pankaj Thakur, Effect of transition stresses in a disc having variable thickness and poisson's ratio subjected to internal pressure, *WSEAS Transactions on Applied and Theoretical Mechanics*, Vol. 6, Issue 4, pp. 147-159, 2011.
21. Pankaj Thakur, Creep Transition stresses of a Thick isotropic spherical shell by finitesimal deformation under steady state of temperature and internal pressure, Thermal Science, Vol. 15, Supplementary issue 2, pp. S157 – S165, 2011.
22. Pankaj Thakur, Elastic-plastic Transition stresses in rotating cylinder by finite deformation under steady-state temperature, Thermal Science, Vol. 15, No. 2, pp. 537-543, 2011.
23. Pankaj Thakur, Deformation in a thin rotating disc having variable thickness and edge load with inclusion at the elastic-plastic transitional stresses, *Structural integrity and life*, Vol. 12, No. 1, pp. 65-70, 2012.
24. Pankaj Thakur, elastic-plastic transitional stresses in a thin rotating disk with loading edge stresses in a thin rotating disc of variable thickness with rigid shaft , *Journal of Technology for Plasticity*, Serbia, Vol. 37, Number 1, pp. 1 – 14, 2012.
25. Pankaj Thakur, S.B. Singh and Jatinder Kaur (2013) Transitional stresses analysis in thin Rotating Disc for different Materials, Proceeding of International Conference On information and Mathematical Sciences (IMS-13), 24-26 Oct., 2013, Elsevier Proceeding , pp. 427-430, 2013.
26. Pankaj Thakur, Jatinder Kaur and S. B. Singh, Thermal creep transition stresses and strain rates in a circular Disc with shaft having variable density, Engineering Computations, Emerald Publisher UK, Vol.33, Issue 3, pp. 698-712, 2016.
27. Pankaj Thakur, Gaurav Verma, D. Pathania and S.B. Singh, Thermal Creep stress and strain analysis in Non-homogeneous Spherical shell, Journal of Theoretical and Applied Mechanics, Warsaw University of Technology Poland, Vol. 55, No. 4, pp. 1155-1165, 2017.

28. Pankaj Thakur, Gaurav Verma, D. Pathania and S.B. Singh, Elastic-Plastic stress analysis in a Spherical Shell under internal pressure and steady state temperature, Structural Integrity and Life, issue 1, Vol. 17, pp. 39-43, 2017.
29. Pankaj Thakur, Gaurav Verma, D. Pathania and S.B. Singh, Elastic-plastic Transition on rotating spherical shells in dependence of compressibility, Kragujevac Journal of Science, Vol. 39, pp. 5 -16, 2017.
30. Pankaj Thakur, Nishi Gupta and S. B. Singh, Creep strain rates analysis in cylinder under temperature gradient materials by using Seth's theory, Engineering Computations, Emerald Publisher, Vol. 34, No.3, United Kingdom, pp. 1031 -1041, 2017.
31. Pankaj Thakur and Monika Sethi, Creep deformation and stress analysis in a transversely material disc subjected to rigid shaft, Mathematics and Mechanics Of Solid, Vol.. 25, No. 1, USA. pp.17-25, 2020.
32. Pankaj Thakur and Monika Sethi, Elastoplastic deformation in an orthotropic spherical shell subjected to temperature gradient, Mathematics and Mechanics Of Solid, Vol.. 25, No. 1, USA. pp.26-31, 2020.
33. R. K. Shukla, Creep transition in a thin rotating non-homogeneous disc, Indian Journal of Pure and Applied Mathematics, Vol. 27, No. 56, pp. 487-498, 1996.
34. R. K. Shukla, Elastic-Plastic transitional stresses in a non-homogeneous disc with variable thickness, subjected to internal pressure, Indian Journal of Pure and Applied Mathematics, Vol. 31, No. 6, pp. 713-720, 2000.
35. Schmidt, R. and Weichert, D., A refined theory of elastic-plastic shells at moderate rotations. ZAMM, Vol. 69, pp. 11–21, 1989.
36. Simo, J.C., Rifai, M.S. and Fox, D.D., on a stress resultant geometrically exact shell model. Part IV: Variable thickness shells with through-the-thickness stretching. Comp. Meth. Appl. Mech. Eng., Vol. 81, pp. 91–126, 1990.
37. S. K. Gupta and R K Shukla, Effect of non-homogeneity on elastic-plastic transition in a thin rotating disk, Indian J. Pure Appl. Math., Vol. 25, No. 10, pp. 1089-1097, 1994.
38. S. K. Gupta and Pankaj, Creep transition in a thin rotating disc with rigid inclusion, Defence Science Journal India, Vol. 57, No. 2, pp. 185-195, 2007.
39. S. K. Gupta and Pankaj, Thermo elastic-plastic transition in a thin rotating disc with inclusion, Thermal Science, Vol. 11, Issue 1, pp. 103-118, 2007.

40. S.K. Gupta, S. Sharma and Sonia Pathak, Creep Transition in a Thin Rotating Disc Having Variable Thickness and Variable Density, Indian Journal of Pure & Applied Mathematics, Vol. 31, No. 10, pp. 1235-1248, 2000.
41. S.P. Timoshenko and J.N. Goodier, Theory of elasticity (3rd ed.). McGraw-Hill Book Coy., New York, 1970.
42. Suresh Hulsurkar, Thermo elastic-plastic transition in rotating disks with steady state temperature, Indian J. pure appl. Math. Vol. 10, No. 5, pp. 567-601, 1979.
43. U. Güven, Elastic-Plastic Rotating Disk with Rigid Inclusion, Mechanics of Structures and Machines, Vol. 27, Issue 1, pp. 117-128, 1999.
44. U. Güven, Elastic-plastic stress distribution in a rotating hyperbolic disk with rigid inclusion, International Journal of Mechanical Sciences , Vol. 40, Issue 1, pp. 97–109, 1998.
45. U. Güven, The Fully Plastic Rotating Disk with Rigid Inclusion, ZAMM, Vol. 77, Issue 9, pp. 714–716, 1997.
46. Weir, C.D. The creep of thick-walled cylinder under internal pressure, J Appl. Mech. (Trans. of ASME), Vol. 79, pp 464- 466, 1957.